(*NEW SERIES*)

No. 38.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA

PRELMINARY REPORT ON THE KILLING OF RATS AND RAT FLEAS BY HYDROCYANIC ACID GAS.

BY

CAPTAIN W. D. H. STEVENSON, M.B., I.M.S.
(*Bombay Bacteriological Laboratory.*)

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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PRELIMINARY REPORT ON THE KILLING OF RATS AND RAT FLEAS BY HYDROCYANIC ACID GAS.

AT the suggestion of Captain W. Glen Liston, I.M.S., experiments with hydrocyanic acid gas, as a measure to exterminate rats and fleas, were commenced in May 1909. The first experiments were made under his supervision.

We were later informed by Mr. Lefroy, the Imperial Entomologist, that large use had been made of this gas by the Agricultural Departments in the United States of America and in South Africa. He kindly sent us some of the literature on the subject along with an account of his own experiments conducted at Pusa, all of which have proved of great help to us.

It will be useful to consider briefly some of the previous work done on this subject. Hydrocyanic acid gas was first used in 1886 by Coquillet in California to destroy the "Cottony Cushion Scale" insect on plants; and later, fumigation of nursery stock with this gas has become compulsory throughout certain of the States. It is now used throughout Canada, the United States of America, South Africa, and Australia, not only for the disinfection of nursery stock, but also as a means of ridding orchard trees of their pests. More important for our purpose is the use of the gas for the disinfection of houses, jails, and railway coaches. The application has naturally been very limited on account of the deadly nature of the gas. Most of the information on this point we have obtained from the Reports of the Government Entomologist to the Cape of Good Hope for the years 1898 to 1901. In 1898 he considered the gas too dangerous for house disinfection; but in 1900, at the request of the Colonial Office, he rid the Worcester jail of the bed bug—"Acanthia lectularia"—by fumigation with hydrocyanic acid gas. A year afterwards the buildings were still free from the pest. In 1901 he further treated two more jails—Tokai and Kimberley—without any accident, although in the latter jail so great a quantity of potassium cyanide was used as 271 lbs. At the time the experiment was completely successful, although a year afterwards the buildings were re-infested. He also notes in 1901 that the "use of the gas for the destruction of vermin in sleeping carriages of the Cape Government railways has now been practised for three years with perfectly satisfactory results and without any accident."

There is also an interesting note to the effect that Professor W. J. Simpson thought this gas might be utilised to cleanse premises in which cases of plague had occurred, and experiments were actually undertaken to determine what minimum strength of the gas might be necessary to destroy bed bugs, which at that time were considered to be possibly the carriers of the plague germ. The experiments were discontinued owing to the decline of the epidemic and the departure of Professor Simpson.

In America also fumigation by this gas has been occasionally used to rid buildings of pests. For example, in the "Proceedings of the 17th Annual Meeting of the Association of Economic Entomologists of America" a paper was read on the fumigation of a four-storey building to get rid of the "Clinocoris lectularia." The building was of about 150,000 cubic feet capacity; 80 lbs. of potassium cyanide were used; the building was kept shut up for two days. All the insects and eggs were killed. "No eggs appeared to hatch afterwards though examination was made frequently for a period of several weeks."

The production of the gas.

The chemicals used—
(1) KCN

In all the work done the gas has been produced by the action of sulphuric acid on potassium cyanide. These chemicals must be of a certain standard of purity to get satisfactory results. With regard to the potassium cyanide, elaborate investigations were carried out, chiefly by Everhart of the Southern College of Pharmacy in the United States of America. His results are detailed by Wilmon Newell in Bulletin No. 15 of the Georgia State Board of Entomology. They generally are that failure to obtain satisfactory results in fumigation has in many cases been due to the use of impure and adulterated cyanide which is often represented and sold as being pure. Of the adulterants sodium chloride is the most important as it produces loss and decomposition of the hydrocyanic acid gas evolved.

Nitrates are another harmful adulterant. The most common adulterant in low grade cyanides being sodium chloride, increased amounts of low grade cyanides cannot be safely substituted for pure cyanide, though they are much cheaper.

A high percentage of potassium cyanide in a sample is not sufficient unless analysis shows the absence of chlorides and nitrates.

Of several different cyanides examined by Everhart, only two, those of Merck & Co. (98—100 per cent.) and of the Baker and Adamson Chemical Co. (99 per cent.) were found to meet all requirements.

In almost all of the experiments detailed in our tables, carried out before we had read Newell's paper, we used 98 per cent. potassium cyanide or Burgoyne Burbidges' potassium cyanide 100 per cent. (double salt). Captain Higham, I. M. S., Assistant to the Chemical Analyser for the Government of Bombay, kindly gave us an analysis of Burgoyne Burbidges' salt. It proved to be a mixture of both potassium and sodium cyanides, yielding 33·9 per cent. hydrocyanic acid equivalent to 81·6725 potassium cyanide.

One hundred per cent. potassium cyanide would yield 41·5 per cent. of its weight of hydrocyanic acid and 100 per cent. sodium cyanide 55·1 per cent. There were no nitrates; but chlorides were present to the amount 3·778 per cent. calculated as hydrochloric acid.

(2) Sulphuric Acid.

The sulphuric acid ought to be commercial concentrated sulphuric acid (specific gravity 1·83).

The proportional amounts of potassium cyanide, sulphuric acid, and water are important. Coquillet in 1889 found that the best results were obtained by using 1 part potassium cyanide, 1 part of sulphuric acid, and 2 of water. But the usage of different workers has varied considerably on this point. However, the majority advocate the 1-2-4 formula, *i.e.*, 1 oz. of 98 per cent. potassium cyanide, 2 fluid ozs. of sulphuric acid, and 4 fluid ozs. of water. The advantage is twofold: (1) There is enough water to dissolve the potassium bisulphate formed and so prevent the deposit of this salt round the potassium cyanide which would reduce the formation of hydrocyanic acid gas. (2) When 2 ozs. of sulphuric acid at 20°C. were mixed with 4 ozs. of water at 20°C. the initial temperature became 110°C.; one oz. of potassium cyanide was added and the whole mixture exposed to the outside air having a temperature of 14°C. for 40 minutes. At the end of that period the mixture had a temperature of 32°C. The boiling point of prussic acid is 26½°C., so that throughout the whole period the temperature was sufficient to volatilize the prussic acid.

If more water is added the initial temperature is less; if less water is added than 4 ozs. the addition of 1 oz. of potassium cyanide would also diminish the initial temperature.

These conclusions were arrived at by Wilmon Newell, as noted in the above-mentioned paper. Some experiments were performed on this point by us.

The room temperature was 28°C.

The initial temperature of both the sulphuric acid and the water was 28°C., quite sufficient for the volatilization of the gas.

I. Three parts of water were added to one part of sulphuric acid.

The initial temperature became 88°C.; after forty minutes the temperature was 43°C.

II. Two parts of water were added to one part of sulphuric acid.

The initial temperature became 105°C.; forty minutes later the temperature was 39°C.

III. One part of water to one part acid.

The initial temperature was 115°C.; forty minutes later the temperature was 41°C.

The end results vary then, not only with the initial temperature developed, but with the bulk of fluid used. In cold climates, as in the Punjab in the cold weather, it would be advisable to mix the various chemicals in one large vessel rather than distribute them in small charges about a room, as cooling of the mixture in the latter case would occur so much more quickly.

Considering every point the use of the 1-2-4 formula is probably the best.

A few minor points advocated by various authorities are:—(1) The use of fairly large lumps of potassium cyanide instead of powdering it. The generation of the gas is too violent with powdered potassium cyanide. Further the powdered salt is apt to deteriorate on standing by exposure to air; and, lastly, there is the increased cost of powdering the salt. If there is a sufficient excess of sulphuric acid and water the inter-action of the chemicals is rapid—almost as rapid with large pieces of potassium cyanide as with small. (F. A. Sirrine, New York Agricultural Department, 1909.)

The Entomologist of the Cape of Good Hope advocates the use of lumps of potassium cyanide, the size of an egg for one lb. charges and lumps the size of an acorn for small charges.

(2) The acid ought to be poured into the water if splattering of the acid is to be avoided. The potassium cyanide ought to be added last. The maximum effect of the gas is then produced.

(3) The storage of the potassium cyanide is of importance as under exposure to air and moisture it deteriorates rapidly. After a case containing potassium cyanide has been opened means ought to be taken to prevent ingress of air and moisture. It ought to be kept in a cool dry place. The same precautions are necessary to keep the sulphuric acid from absorbing moisture.

Methods of carrying out Fumigation recommended by previous workers.

(1) *The quantity of potassium cyanide to be used per cubic space to be fumigated.*

There is some difference of opinion with respect to this point.

Burgess of Ohio in a paper on "Fumigation of Nursery Stock" states: "A series of experiments in treating peach buds made in August 1902 showed that $\frac{5}{4}$ oz. of cyanide to each 100 cubic feet of space for 40 minutes' exposure killed all *San Jose scales* and no injury resulted to buds."

Newell of the Georgia State recommends 1 oz. of 98 per cent. potassium cyanide to 100 cubic feet. With this dosage he states that "trees heavily infested with the San Jose scales and protected with a heavy layer of earth failed to show any live scale insects within a year of being fumigated."

Sirrine advises 25 grammes of potassium cyanide per 100 cubic feet; or for orchard trees, owing to the moisture and absorption of the evolved hydrocyanic acid gas, 30 grammes, *i.e.*, about 1 oz. to 100 cubic feet.

The Government Entomologist for the Cape of Good Hope in his Report for the year 1901 states that bugs are more refractory to the gas than any other house insect. One ounce of potassuim cyanide to 155 cubic feet of air space with an exposure of one hour killed 12 out of 15 bugs. The remaining 3 were very feeble. Eggs of the bugs failed to hatch in three tests after exposure for one hour to gas of the above strength.

He advises the use of one ounce to 100 cubic feet of space and an exposure for two hours. "When there are any deep cracks or crevices in any building to be penetrated, one ounce to 60 cubic feet of space may be used."

(2) *Actual procedure to be adopted as advised in the report of the Government Entomologist for the Cape of Good Hope for the year 1901.*

The building to be fumigated is made as air-tight as possible. Arrangements should be made for opening doors and windows from the outside to ventilate after fumigation. Each room should be fumigated separately, if possible, but sometimes two connecting spaces may be treated as one. In the latter case crevices and splits in doors connecting the two spaces should be enlarged and burrows opened up. Bedding, clothing, etc., should be spread out to let the gas get full effect on them.

The vessels in which the chemicals are to be mixed must be of such a nature that they are not acted on by them. Their size depends on the quantity of chemicals to be used. They must be of such a shape that the depth of combined sulphuric acid and water will cover the cyanide put in. They may be glazed earthenware vessels or china washhand vessels. Lead vessels are good but heavy and soft. Enamelware till cracked acts well. Kerosine oil tins will serve for two or three different charges. One of these tins can take a charge of 3 lbs. of potassium cyanide—the utmost that ought to be put into one vessel. Place the vessel near the middle of the room. Measure out quantities of water, acid, and potassium cyanide. The man who measures out the potassium cyanide ought to handle it with rubber gloves as the salt is so poisonous. Mix the acid into the water, at once drop in the potassium cyanide at arm's length, and run out of the room. Many people wrap up the potassium cyanide in soft paper which takes a few seconds to be eaten through, permitting the operator to get out of the room before the gas is given off. The American fumigators usually lower the potassium cyanide by means of a string and pulley from the outside after the door of the room to be fumigated is locked. As the hydrocyanic acid gas rises, being lighter than air, if there are two storeys begin at the top ; and if there are many rooms in a corridor begin at the farthest from the exit. An assistant may go in front mixing the acid and water. Great quickness and care are essential as the gas is so poisonous.

Of course if a tenement is to be disinfected all inhabitants must be cleared out first. It is essential to have a clear space round the building to be fumigated. It is recorded in one of the American experiments that persons walking 100 feet from the building could detect the odour of the gas the whole time.

The period of exposure should be two hours at least. It is better not to try ventilation till 12—24 hours have elapsed. So far as we have seen in our experiments (with the 1-2-4 formula) in 50 minutes the action of the sulphuric acid on the potassium cyanide has been completed. So really the ventilation of the building can be carried out in two hours if the doors and windows can be opened from the outside. It is at the moment of entering the building after fumigation that danger is most to be guarded against.

After opening the doors and windows from the outside certainly half an hour should elapse before any one enters the building, and it is safer to wait three hours. It depends altogether on the character of the building and if there are many doors and windows which can be opened from the outside. We have entered a room five minutes after the delivery of the gas has stopped. There is a very good test suggested to us by Captain Dickinson, the Chemical Analyst of Bombay. It depends on the formation of prussian blue by the gas if there is any free in the room. A paste is made up consisting of ferrous sulphate and caustic potash. A little is put on a rod of glass and the rod introduced into the room. It is exposed to the air of the room for five minutes. If hydrocyanic acid gas is present sodium ferrocyanide is formed. A few drops of pure hydrochloric acid are then run on the paste and a little water containing a few drops of ferric chloride added in a beaker. If there is any hydrocyanic acid gas at all in the room blue colour is formed—deep blue if much gas ; faint green blue if a little. If only a yellow colour is present it is quite safe to enter the room. This is a most delicate test. It will detect $\frac{1}{780}$ grain of hydrocyanic acid in a very dilute liquid (Watt's Dictionary of Chemistry). It is much safer to rely on this test than on the odour of almonds, as the sense of smell seems to be paralysed by the diluted gas after the first few whiffs. Even a trace of hydrocyanic acid in the air leads to headache and nausea. It is so deadly that a whiff of fairly strong gas kills at once.

It is obvious that the greatest care must be taken during the whole procedure. No naked lights should be left about a building as hydrocyanic acid gas is somewhat inflammable.

The action on animals, insects, plants, food, and fabrics.

Our experiments have been almost entirely on rats and rat fleas, and will be detailed later. With respect to its action on certain insects, arachnoids and mammals, Lounsbury states that flies are much more susceptible to the gas than fleas, and fleas than bed bugs. *Argas persicus*—the tick of the fowl—is the most refractory. "The eggs of the bed bug and of the flea (at least of the dog flea, *Pulex serraticeps*) are devitalized almost, if not quite as readily as the parent insects." Rats and mice are also readily killed.

On the subject of the action of the gas on plants a vast amount of literature is available. Generally speaking the amounts of chemicals recommended above as sufficient for fumigation do not destroy even delicate plants.

The action on foods and water is of importance. It is agreed that dried grain is not made poisonous by the action of the gas.* An experiment was performed by us on that point. Into a fairly air-tight room of 830 cubic feet capacity the gas evolved from 340 grammes of 98 per cent. potassium cyanide (equivalent to about 1½ ozs. to 100 cubic feet air space) was introduced. The amount of hydrocyanic acid gas was calculated to be about 4·38 cubic feet at 26° Centigrade. It was allowed to act for 20 minutes. Fleas were found dead after 5 minutes' exposure to the air of the room. The test rod showed a plentiful supply of hydrocyanic acid gas to be present by the development of prussian blue. The grains tested were: (1) *bajri*, (2) wheat, (3) *jowari*, (4) *mula* or radish, (5) rice. *Bajri*, wheat, and rice were put into kerosine oil tins. A pipe bringing in gas diluted with air (the mixture was driven in by a fan from the generating flasks) was led to the bottom of the mass and another pipe was directed on its surface. *Mula* and *jowari* were in small amounts and the gas mixture was directed on their surface only.

Monkeys, rabbits guinea-pigs, hens, and pigeons were fed on the grains for twenty-four hours; none became ill.

Chapatis were made of the wheat, *jowari*, and *bajri* and given to monkeys and hens with no ill-results.

On the other hand moist food-stuffs, such as water, milk, butter, and flesh, are said to absorb the poison. We have not tried experiments on this. Meat and water exposed to the gas are said by Lounsbury to have proved fatal to dogs.

Therefore, during the fumigation of a building, all such moist food-stuffs ought to be removed. Dry food-stuffs can be left alone, but had better be thoroughly aired before use.

Another question is: "Does the gas injuriously affect the germinating powers of the grain?" This is of importance in view of the amount of grain stored in native houses to be used later for sowing.

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* Report of Government Entomologist to Cape of Good Hope, 1901.

As all the experience of workers in America and South Africa goes to show that even delicate plants are not injured by the gas when present in sufficient concentration to clear them of insects, the answer would be that it is not injurious. An experiment we did confirmed this. Certain amounts of the above grains subjected to the gas were planted, and their growth compared with control grains which had not been fumigated. No difference in the rate of growth could be detected. So during a fumigation, stored dry grain can be left in the house without fear of rendering it poisonous or of destroying its germinating power.

Unlike Sulphur dioxide gas hydrocyanic acid gas has no action on metals or fabrics.

The action of the gas on bacteria.

About 4·38 cubic feet of diluted gas were introduced into a room of capacity 830 cubic feet and allowed to act for twenty minutes on bacteria. Cultures of *streptococci*, *Bacillus typhosus*, *Bacillus coli*, and *Bacillus pestis* on agar slopes in test tubes with their cotton-wool stoppers removed were put in the room. After the experiment subcultures on agar showed that the plague was overgrown with a yellow contaminating organism. The other bacteria had not been killed by the action of the gas.

This coincides with the experience of the Government Entomologist of the Cape of Good Hope as noted in the Report for 1901: "Cultures of the plague bacillus were found to be unaffected when exposed by substituting a piece of gauze tied over the top for the plug of cotton-wool ordinarily used for stopping culture tubes by one hour in 1 to 80 gas—the severest test employed."

Disinfection for plague.

Its harmless effect on the plague bacillus does not condemn hydrocyanic acid gas as a preventive for the spread of plague. Preventive measures for this disease fall under two heads:—

(1) Disinfection of clothing of railway and other travellers. This is equivalent to the destruction of plague germ carriers, namely, fleas.

(2) Disinfection of plague houses. This is equivalent to the destruction of plague rats and of plague fleas.

I.—The use of hydrocyanic acid gas for the disinfection of clothing.

There is no question of its great efficiency, its cheapness, and the rapidity with which the operation can be carried out—all matters of importance. It has further the advantage of having no destructive effect on fabrics.

Our experiments were carried out in two ways:—

(*a*) *First method.*—Potassium cyanide was mixed with sulphuric acid and water (1 of sulphuric acid to 19 of water) at first in glass flasks and in later experiments in a specially constructed leaden vessel. The mixture was heated over a Bunsen flame, the whole being placed outside the room to be fumigated. Tubes conducting the undiluted gas were led directly into the room in some cases; in others the tubes were led into a large iron vessel from which the gas was pumped by a powerful fan into the room through a large delivery pipe. There was a second opening in the iron vessel through which air was pumped and mixed with the hydrocyanic acid gas. It was the largely diluted hydrocyanic acid gas that was introduced. The quantities of hydrocyanic acid gas produced were calculated as follows: about 82 grammes of pure potassium cyanide taken as 100 per cent. will produce 1 cubic foot of hydrocyanic acid gas. We used for one charge 85 grammes of 98 per cent. potassium cyanide or the equivalent amount of other strengths of the salt. We were at the time unaware of the necessity of using sodium chloride free potassium cyanide stated by Wilmon Newell in his paper and quoted above on page 2.

With the 85 grammes of potassium cyanide we mixed 35 c.c. of strong commercial sulphuric acid diluted to 700 c.c. with water (*i.e.*, H_2SO_4 1 in 20 strength).

The room in which these experiments were carried out is comparatively air-tight. It is of the following dimensions: length 12 feet 6 inches; breadth 7 feet 8 inches. The roof slopes upward from a wall 5 feet 8 inches to one of 11 feet 8 inches. The cubic capacity is about 830 cubic feet. The walls are of cement. The floor is of stamped earth. The roof is of corrugated iron made rat-proof by being firmly fastened to the walls. There is a large window 2 feet 7 inches by 3 feet 6 inches and opposite it a large door 3 feet 2 inches by 5 feet 6 inches. The window is capable of being tightly closed by shutters. Through the shutters the delivery pipe was led into the room. The door, which leads into another room, was closed and any cracks or obvious holes sealed over, so that a comparatively air-tight chamber was produced.

In the different experiments varying amounts of gas from 2 to 4·38 cubic feet were introduced into the room for different periods of time.

The results giving details of amounts of gas used, the time of exposure, and the effect on fleas in different situations are given in Experiments I to VI.

Rats were introduced into the room simply to discover what amount of gas would be necessary to kill them. They require more gas and a longer exposure than fleas. But the effect of the gas on them is of no importance for this investigation—namely, disinfection of clothing.

Two points were aimed at: (*a*) to obtain a sufficient penetration of clothes, and (*b*) to conclude the whole operations in a short period of time, so that no great delay to the persons waiting for the clothes would occur.

Both objects were attained. Bundles of clothes wrapped fairly tightly up were thoroughly penetrated by the gas. A consideration of the tables will show this. For example, in Experiment I the gas penetrated through four bags, —three of coarse blanket and one of cotton, killing 10 fleas out of 11 placed centrally. It penetrated through three bags, two of blanket and one of cotton killing all the fleas placed centrally. The gas was led direct from flasks outside the room without the use of a fan. About two cubic feet of gas were introduced into the above described room of 830 cubic feet capacity and the time of exposure was 51 minutes.

Experiment II shows the same condition of affairs as Experiment I, but a shorter exposure of 30 minutes with not so successful a result.

The most successful experiment is No. III. About 4·38 cubic feet of gas were pumped into the room by a fan for 20 minutes and then the delivery of gas was stopped. The gas was distributed by nine small tubes throughout the room. The fleas in all parts of the room were killed, even though the tubes containing them were wrapped up in several layers of thick sheeting and blanket. But in series 3 where they were surrounded by a durree, blanket, and coat very tightly rolled, eight fleas remained alive out of nine. Fleas put in cages with bran and sand at the bottom were all killed in this experiment, showing that there is a certain penetration of the gas into these substances,—an important point in the disinfection of houses, as the fleas bury themselves in dust, grain, etc.

If clothes are left loosely in boxes, can we say the gas will penetrate sufficiently to kill ? If so, it would obviate the necessity of hanging out the clothes for disinfection.

Experiments IV and V were tried to determine this point. If pipes were led with great care into the boxes, fleas were killed. But it will be noted that failure occurred in some instances, where, perhaps, owing to the tube being kinked, some obstruction to the entrance of the gas occurred. It is much safer to hang up the clothes on pegs or scatter them loosely about the room.

In Experiment IV it is noted that the room was entered in 30 minutes from the commencement of the operations. The disinfection of the clothes was very thorough, so that it is possible by pumping gas into a room to kill fleas in clothes and deliver clothes back to their owners in thirty minutes. The use of the test rod mentioned on page 6 enables one to enter the room with safety.

(*b*) *Second method.*—The fan and pipes are, however, a complicated and expensive means of distributing the gas. Accordingly the method of producing the gas, as detailed on pages 5 and 6, was tried.

A flea-tight and very air-tight godown—one of those used in the Plague Commission's experiments—was taken. Its cubic capacity is about 346 cubic feet. Into a small china vessel 4 ozs. of water were put, 2 ozs. of commercial strong sulphuric acid were added evolving heat, and then 1 oz. of potassium cyanide was finally put in and the door closed. The gas was left in contact with the clothes for forty minutes and then the door was opened. The room was entered fifteen minutes later. The fleas left in different parts of the room were all killed,—the gas even penetrating through four bags, three of blanket and one of cotton, killing all the fleas placed centrally. Fleas were put in various situations in a box full of clothes; some escaped. For details see Experiment X.

So again it was shown that it is necessary to take the clothes out of a box and hang them up. The strength of gas used was less than one-third that suggested by fumigators elsewhere (1 oz. to 100 cubic feet); yet it was completely successful. The action of the sulphuric acid on the potassium cyanide is not completed for forty minutes probably, as when the door was opened in the above experiment fumes were still being evolved from the generating pot. After sixty minutes the evolution of gas is completed. Accordingly some means must be thought of to cut off the supply of gas, say after fifteen minutes, to allow one to enter the rooms safely and give the clothes back quickly to their owners. That the fleas are killed in five minutes was shown in one of our experiments. In five minutes after the commencement of the evolution of gas a tube containing fleas was withdrawn; they were all dead.

In another experiment larvæ of rat fleas loose on sand were subjected to the same strength of gas, 1 oz. potassium cyanide to 346 cubic feet for an hour. They were all killed. Controls were all living at the time of examination. Eggs and cocoons of the rat flea were subjected to a stronger gas, 1 oz. to 100 cubic feet. The eggs were all killed. Larvæ hatched out of control eggs not subjected to the gas but otherwise under the same conditions.

All the cocoons, however, were not killed by the gas.

But the important point is to kill infected fleas. Infected fleas have not been shown to transmit plague bacilli to their eggs.

II.—The Disinfection of Plague Houses—that is to say, the destruction of rats and fleas in these houses.

A room was chosen which presents the characters of most native huts in Bombay,—that is to say, not at all air-tight. Its length is 12 feet 6 inches; breadth 15 feet 7 inches; height at one end 5 feet 6 inches; at the other end 11 feet 4 inches. The cubic capacity is 1,640 cubic feet. The floor is of stamped earth and the roof of country tiles. Below the edge of the roof and the smaller end wall a small space communicates with the outside. There is also very free ventilation between the edges of the tiles. There are two large windows which can be well closed with shutters and two doors, one of which communicates with the outside and one with the small room described on page 9.

In the following experiments as many of the large ventilating holes as could be filled up were closed with tightly packed paper and the room was made as air-tight as most native huts can be made.

In the floor of the room four types of rat burrows were present, each consisted of a small wooden box to contain rats and fleas and one or two passages leading from it to the floor of the room. The boxes measured 21 by 10¾ by 12 inches. They are fitted with hinged lids and are sunk in the ground. Inside each box is a rack to hold test-tubes containing fleas. The cage for the rat can be placed inside the box. The channels consist of a series of short sections of earthenware pipes sunk in the ground. Each section is made up of concave country roofing tiles placed together to form a somewhat tapering pipe, the narrow end of one section fitting into the broad end of the other. The narrow end of the lowest of these sections projects slightly into the box. These "burrows" measured from 5½ to 12 feet.

There are four types of burrows:—

Type A.—A blind burrow with a single opening.

Type B.—A blind burrow with a single opening inside the room. The box for the cage was outside the room for facility of observation.

Type C.—Two burrows with S-shaped curves on the horizontal, leading to the box containing the cage.

Type D.—Same as type C, but with the curves vertical.

Over the tiles 4 to 6 inches of earth were placed and, after the fleas and rats had been placed inside, the lids of the boxes were carefully sealed down with moist clay.

These burrows and observation chambers were originally devised by Captain Gloster, I.M.S., for his experiments with the Clayton gas apparatus.

The results of experiments in this room are detailed in Experiments VII to IX.

Experiment VII shows the results when the gas was generated outside the room and introduced by tubes without pumping. Some tubes were also led a little distance into the burrows and the mouth of the burrows closed up. The gas is lighter than air and better results were obtained at the upper layer of the room than on the floor. Neither rats nor fleas in the burrows were affected by the gas. At the level of the floor many fleas in cages with sand at the bottom managed to escape by burrowing into the sand, while those in bran were killed.

In Experiment VIII the gas was introduced by larger calibre tubes and pumped in by a fan; four of the tubes were led into the burrows and the mouth of the opening closed up with mud round the pipe. This was a most successful experiment. Fleas in all situations,—in the room, in cages with sand and bran at the bottom, and in test-tubes in the burrows,—were killed. Six out of eight rats on the floor or 4 feet above floor level were killed and seven rats at higher level were all killed. The rats in burrows A and C were killed. There was some obstruction in burrow D preventing all the gas entering. Burrow B was the observation burrow and was opened during the experiment when the rat was found to be sick. The whole experiment was completed in forty minutes with an introduction of about 4·38 cubic feet of the gas equivalent to 340 grammes of 98 per cent. potassium cyanide about $\frac{3}{4}$ oz. to the 100 cubic feet space.

Experiment IX.—Rats loose in the burrows were also killed.

Attempts were made to dispense with the complicated apparatus of fans and tubes by generating the gas inside the room, as described on pages 5 and 6. They are detailed in Experiments XI and XII. At higher levels of the room rats and fleas were killed, but rather unsatisfatory results were obtained at floor levels, and the experiment was an absolute failure in the burrows, both rats and fleas escaping.

Therefore, with artificially constructed burrows and the use of an apparatus with a fan to pump in the gas small rooms can be disinfected thoroughly in, say one hour.

Whether natural burrows can be penetrated by the gas remains to be proved. As the gas is so poisonous, special permission must be obtained before experiments can be carried out. As far as we can see at present with small isolated huts when the inhabitants are all cleared out there would be no danger. The inhabitants could return with perfect safety in two hours after ventilation was begun, but to make it absolutely sure, say twelve hours.

When houses are placed close together, as in a Punjab village, the whole would require to be evacuated simultaneously for two reasons :—

(1) As rat burrows run from one house to another the gas produced in one house might find ingress into others causing great danger to the inmates. The faint almond odour of the gas and the taste at the back of the throat is only appreciated for the first few moments. The gas then paralyses the sensory nerves and though dangerous quantities may be present they would not be appreciated.

(2) For a successful experiment such contiguous houses should be done simultaneously in order that no rats may escape.

With tenements in cities like Bombay evacuation of the whole tenement would be necessary for the same reasons. Further, a clear space round is a necessity, as even when only 4 ozs. of potassium cyanide were used in a small godown the odour of the gas was perceived twenty feet away when the door was first opened. See also on this point what is noted above on page 6. For these reasons the wholesale use of the gas is impossible. It ought first to be tried isolated houses to investigate its action on rats under natural conditions. The investigation should be made by some one familiar with the use of the gas.

Cost of Disinfection.

I.—Disinfection of clothes.—As we have stated above, an air-tight godown must be built with arrangements for letting the gas play on the clothes for, say, fifteen minutes and then turning off the supply of gas to allow of safe entry to the building. This would be necessary if the clothes are to be returned to their owners in a reasonable time. The advice of an engineer is requisite for the construction of the godown as the danger from the gas is not to be underrated. The price of the chemicals is slight.

The cost of potassium cyanide (98—100 per cent.) is 1 shilling per lb. for 28 lbs., or 99 shillings a cwt. if bought in bulk (Merck's quotation). The cost of sulphuric acid is 1*d.* (one penny) per lb. if carboys are bought (Baird & Tatlock's quotation).

Suppose the room was of 1,000 cubic feet capacity and moderately air-tight, 7½ ozs. of potassium cyanide and 15 ozs. of sulphuric acid would be required. The total cost of chemicals for disinfection would be between 6 pence and 7 pence plus the pay of a supervisor. China vessels to hold the chemicals would last indefinitely.

II.—Cost of disinfecting houses.—We have got a machine adapted for experiments in single rooms and we could use it for experiments on houses with natural burrows. Some extra lengths of tubing might be necessary, but the cost would not be great.

The conclusion then is that so far as disinfection of clothes is concerned we have in hydrocyanic acid gas a very cheap and efficient pulicide. With a specially constructed godown, it would be possible to deliver over to their owners clothes absolutely free of fleas in half-an-hour. There would be no damage to fabrics. If proper precaution is taken and an experienced man acts as supervisor no accident should occur.

With regard to the disinfection of houses the conclusions arrived at are not so satisfactory. We desire permission to use this gas in isolated huts with natural burrows. With artificially constructed burrows good results have been obtained. If as satisfactory results can be got with natural burrows we have an efficient means of clearing houses of plague rats and fleas. But the means are not without danger. This danger could be largely guarded against in isolated houses with a clear space round them, or in an aggregation of houses with a clear space round them, as in a village, if evacuation of the houses could be insisted on till such time as occupation be declared safe. In crowded localities, as in tenements in cities, the danger is too great to permit employment of the method.

Experiment I.*

A.

Fleas and rats were placed in the small room described on page 9 of 830 cubic feet capacity. 170 grammes of 98 per cent. potassium cyanide, equivalent to about ¾ oz. of the salt to 100 cubic feet air space, was decomposed outside the room. The resultant gas calculated to be about 2·19 cubic feet at 26° Centigrade was led into the room by tubes without the use of a fan to drive it in. The generation of gas took 51 minutes.

The object of this experiment with fleas was to test the penetration of gas through various layers of cloth stuffs.

Details of covering, etc., enclosing the fleas.	Results after 51 minutes' exposure to the gas.	REMARKS.
(*a*) 15 fleas were put in a white cotton bag and that again enclosed in one bag of coarse red blanket.	(*a*) All fleas were found dead.	
(*b*) 9 fleas in a white cotton bag were enclosed in two layers of coarse red blankets.	(*b*) Do.	
(*c*) 11 fleas in a white cotton bag were enclosed in three layers of coarse red blankets.	(*c*) 10 dead; 1 alive.	
(*d*) 11 fleas were put in a fine flannel bag.	(*d*) All fleas dead.	
(*e*) 9 fleas were put in a chintz bag .	(*e*) Do.	
(*f*) 10 fleas were put in a cashmere bag	(*f*) Do.	
(*g*) 20 fleas were put in a single chintz bag and that rolled in a durree, blanket, coat and trousers.	(*g*) 7 escaped; 12 alive; 1 dead.	

* NOTE.—In Experiments I to IX inclusive the potassium cyanide was stated to be of 98 per cent. strength.

Experiment I—*contd.*

B.

Rats and fleas were put in various positions on the floor—the rats in cages and the fleas in test-tubes with the glass end removed and both ends covered by some netting to allow of proper diffusion of the gas.

POSITION.	RATS.			FLEAS.		REMARKS.
	Dead.	Sick.	Alive.	Dead.	Alive.	
On the floor . .	...	1	2	...	...	
4 feet from floor . .	2	...	1	...	...	
7 do. . .	...	1*	...	All	...	* Escaped, but found outside sick.
10 do. . .	...	1	2	All	...	
15 do. . .	..	1	2	All	...	

C.

Twenty fleas were placed in each of four cages,—two containing sand at the bottom and two bran. At the end of 51 minutes the cages were examined and guinea-pigs put into the cages on three separate occasions to recover the fleas.

CAGES.	No. of fleas put into each cage.	Result, *i.e.*, recovered alive after exposure of 55 minutes.	REMARKS.
Cage No. 1 with bran at the bottom.	20	4	
Cage No. 2 with bran at the bottom.	20	None.	
Cage No. 1 with sand at the bottom.	20	2	
Cage No. 2 with sand at the bottom.	20	2	

For a control to this, see the end of Experiment III.

Experiment II.

A small room was used—of 830 cubic feet capacity. The same amount of hydrocyanic acid gas as in Experiment I was introduced without the use of a fan. The exposure to the gas was for *half-an-hour* only.

POSITION.	RATS.			FLEAS.		REMARKS.
	Dead.	Sick.	Alive.	Dead.	Alive.	
On the floor	1	...	1	...	...	
4 feet from floor	1	...	2	All	...	
6 do.	...	2	...	...	...	
10 do.	...	2	...	All	...	
12 do.	...	1	...	All	...	

Experiment with Fleas.

Details of covering, etc., enclosing the fleas.	Results after 30 minutes' exposure to the gas.	REMARKS.
(*a*) 11 fleas were put in a white cotton bag and that again enclosed in one bag of coarse red blanket.	(*a*) 9 alive; 2 dead.	Another cotton bag containing 11 fleas was put between two layers of blanket and two of cretonne—all dead. In this case a pipe discharged the gas on the top of the blanket.
(*b*) 12 fleas in a white cotton bag were enclosed in two layers of coarse red blanket.	(*b*) 7 alive; 5 dead.	
(*c*) 12 fleas in a white cotton bag were enclosed in three layers of coarse red blanket.	(*c*) 10 alive; 2 dead.	
(*d*) 17 fleas were put in a fine flannel bag.	(*d*) All dead.	
(*e*) 14 fleas were put in a chintz bag	(*e*) All dead.	
(*f*) 15 fleas were put in a cashmere bag	(*f*) All dead.	
(*g*) 10 fleas were put in a single cotton bag and that rolled in a durree, blanket, coat, and trousers.	(*g*) All alive.	

Experiment III.

A small room of 830 cubic feet capacity was used. 340 grammes of 98 per cent. potassium cyanide, equivalent to about 1½ ozs. of the salt to 100 cubic feet air space, was decomposed outside the room. The resultant gas, calculated to be about 4·38 cubic feet at 26° Centigrade was delivered into the room by means of a fan. Exposure for *20 minutes.*

Details as to conditions under which the fleas were admitted to the action of the gas.	Results of fumigation.	REMARKS.
(1) 10 fleas in a cotton bag wrapped in several layers of blanket and thick sheet.	(1) All dead	In all these results the fleas were kept for two hours and looked at again—in no case did any flea show signs of life.
(2) 8 fleas in a bag at the foot of a box containing boots, deckshies (copper vessels), and some clothing.	(2) All dead.	
(3) 9 fleas in a bag wrapped in a *durree*, blanket, and coat rolled tightly up.	(3) 8 alive; 1 dead	Control fleas kept in bags in precisely the same conditions as those shown herein were found at the end of two hours to be all alive.
(4) 9 fleas in a cotton bag on top of a box.	(4) All dead.	
(5) 8 fleas in a cotton bag wrapped up in a *durree* and 3 blankets, fairly tightly rolled up—a pipe discharging gas was put at the mouth of the roll.	(5) All dead	4 cages, 2 with bran and 2 with sand at the foot, were placed on the floor. 20 fleas were put in each. After fumigation guinea-pigs were put three times into each box. No fleas were recovered, so presumably all were killed by the gas.
(6) 9 fleas in a cotton bag hanging 5½ feet from the floor.	(6) All dead.	
(7) Bag 'A' as in Experiments I and II, that is, 8 fleas in a cotton bag enclosed in a red blanket bag 5½ feet from the floor.	(7) All dead.	
(8) Bag 'B,' same as above, but two layers of blanket bags.	(8) 7 fleas; all dead	In control cages guinea-pigs were put in; recovered 21 out of 40 fleas from the 2 sand cages, and 19 out of 40 from the 2 bran cages.
(9) Bag 'C,' same as above, but three layers of blanket bags on the floor.	(9) 8 fleas; all dead.	
(10) 8 fleas in a test-tube on the floor.	(10) 8 fleas; all dead.	

Experiment IV.

In disinfection of boxes do the clothes need to be taken out of boxes and hung up; or can we thoroughly disinfect clothes by leading pipes into the boxes?

Two experiments were done on this point.

The same amount of hydrocyanic acid gas as in Experiment III was pumped into the small room of 830 cubic feet capacity (about 4·38 cubic feet). The exposure was for 20 minutes. The room was entered in 30 minutes from commencement of operations. By using the test rod a good prussian blue tint showed that a concentrated gas was passed into the room. Nine pipes took the gas into the room from the generating chamber outside. One pipe was led into the bottom of Box I. Two pipes were led into the bottom of Box II.

In Box I from above downwards fleas were put in the following positions:—

PARTICULARS.	Result.	REMARKS.
A.—9 fleas were in a bag covered by coat, trousers, durree, and blanket.	All 9 alive.	
B.—Lower down rug, 4 blankets, 1 chudder, and durree, then the bag with 8 fleas.	All 8 alive.	
C.—Then a great-coat and 10 fleas below in a cotton bag.	9 alive; 1 dead.	
D.—Then a military blanket, then 7 fleas in bag; then a rug on bottom of box.	4 alive; 3 dead.	

In Box II from above downwards fleas were put in the following positions:—

PARTICULARS.	Result.	REMARKS.
A.—Rug, then bag containing fleas .	All dead . .	No. 2 box much less tightly packed than No. 1 box.
B.—Blanket, pillow, and then bag containing fleas.	All dead.	
C.—Pillow and rug, then bag containing fleas.	All dead . .	20 fleas in 4 boxes, 2 with sand at the bottom and 2 with bran, as before. None recovered; all present dead presumably.
D.—Pillow and rug, then bag containing fleas; 2 pillows at foot of box.	All dead.	

Experiment V.

With Clothes in Boxes.

Same period of exposure 20 minutes. The same amount of hydrocyanic acid gas (about 4·38 cubic feet) as in Experiment III was introduced into the room of 830 cubic feet capacity by means of a fan.

Box I, from above downwards.

PARTICULARS.	Result.	REMARKS.
1. Rug and chudder, then cotton bag with 10 fleas in it.	10 fleas ; all dead.	
2. Then durree and 2 blankets with bag of 7 fleas below.	7 fleas ; all dead.	
3 Then one blanket, with bag of 9 fleas below.	9 fleas ; all dead.	
4. Then a blanket in several folds and a bag with 7 fleas below it.	7 fleas ; all dead.	
5. Then another blanket with 9 fleas below in a bag.	9 fleas ; all dead.	

Box II.—Two pipes were led into Box II, from above downwards.

PARTICULARS.	Result.	REMARKS.
(*a*) Pillow, then 10 fleas in bag .	9 dead ; 1 just feebly living.	The pipes were led into foot of box. Those fleas which were found "feebly living" at the end of experiment remained so for 1½ hours after the experiment.
(*b*) One rug and 9 fleas in bag below it.	6 dead ; 3 feebly living.	
(*c*) Then rug and blanket with 8 fleas in bag.	8 dead, all.	
(*d*) Then rug and pillow with 10 fleas in bag below.	10 dead, all.	

Experiment VI.

Does the gas kill cultures of micro-organisms and what effect has it on the germinating power of grains? Does it render dry food-stuff poisonous?

The small room of 830 cubic feet capacity was used. About 4·38 cubic feet of hydrocyanic acid gas was introduced by a fan and allowed to act 20 minutes from the start. The test rod showed plenty of gas to be present.

The grains tested were: (1) *Bajri*, (2), Wheat, (3) *Jowari*, (4) *Mula* or Radish, and (5) Rice.

(1), (2), and (5) were put in kerosine oil tins. A pipe conveying the gas was conducted to the bottom of the mass and one was directed on the surface. *Mula* and *jowari* were in small amounts and gas played on their surface from pipes directly placed on them.

I. Were the grains poisonous?

No. Tested on monkeys, rabbits, guinea-pigs, hens, and pigeons. Fed on it for 24 hours. None dead nor ill. Again *chapatis* were made of the wheat, *jowari*, and *bajri*, and monkeys and hens were fed on them. No ill results.

II. The germinating power of the seeds was not affected. Certain quantities of the above grains were planted and seeds not subjected to the gas were planted at the same time to serve as control in the comparison of the rate of growth.

Both examples of *bajri*, *jowari*, and *mula* grew well; of wheat grew feebly, because much of it was husked.

Cultures of (*a*) Micrococcus melitensis, (*b*) Cholera spirillum, and (*c*) Bacillus anthracis, were placed in the room, but the cotton-wool stoppers were not removed from the test-tubes containing the cultures as it was thought not to be safe to do so. They were after subjection to the gas re-transplanted on agar and showed good growths.

Test-tubes containing cultures of (*a*) Streptococci, (*b*) Bacillus typhosus, (*c*) Bacillus coli communis, and (*d*) Bacillus pestis, were placed in the room with their cotton-wool plugs removed, so that the gas had full action on the germs. After the experiment the germs were recultured on agar. The Bacillus pestis was overgrown with some yellow contaminating organism. The others grew well and seemed to the naked eye to be pure cultures.

So probably the above germs are not affected by the gas.

Fleas after 5 minutes' exposure to the gas were found dead. They were put into tubes and withdrawn after 5, 10, and 15 minutes' exposure, all dead.

Experiment VII.

The following experiments—VII, VIII, and IX—were performed in the large room. Description of room and burrows will be found on pages 11 *et seq.* The cubic capacity is about 1,640 cubic feet. In Experiment VII the gas was delivered into the room without fan by tubes led from flasks outside the room. Potassium cyanide of the strength of 98 per cent. to the amount of 255 grammes (equivaent to about ·56 ozs. of the salt to 100 cubic feet air space) was decomposed. The resultant hydrocyanic acid gas was calculated to be about 3·28 cubic feet at 26° Centigrade.

In 10 minutes after the cyanide and acid were mixed sufficient gas was evolved to give a decided result with the test rod.

The exposure to the gas was for 45 minutes.

POSITION.	RATS.			FLEAS.		REMARKS.
	Dead.	Sick.	Alive.	Dead.	Alive.	
Rats on wall . .	3	3	1	20 (all)	...	
Hanging from rafters (10—15 feet).	...	1	1	All	...	
15 feet from floor .	...	...	1	All	...	
The tubes were introduced into the burrows 1½ feet.						
Burrow A	...	...	1	...	All.	For description of burrows, see page 12.
„ B	...	...	1	...	All.	
„ D	...	...	1	...	All.	

Fleas were placed in 4 cages, 2 of bran and 2 of sand on the floor.

CAGES.	No. of fleas put into each cage.	Results, *i.e.*, recovered alive after 45 minutes' exposure.	REMARKS.
Cage No. 1 with bran.	40	1 was recovered after fumigation.	The counts were made by means of guinea-pigs in all these cases
Cage No. 2 with bran.	20	None recovered.	
Cage No. 1 with sand.	20	12 were recovered . .	For a control to this see the end of Experiment III.
Cage No. 2 with sand.	20	14 were recovered.	

In this experiment the gas proved so light that it was most effective at the upper levels of the room; many fleas in cages on the floor escaped, especially those in cages with sand at the bottom in which they buried themselves. Both fleas and rats in the burrows escaped, even although the tubes were led into the burrows a little distance.

Experiment VIII.

Another experiment was tried with the following alterations : (1) the fan was worked ; (2) the tubes leading off from the main tube were larger in calibre and their total surface area equal to the surface area of the large tube leading from the generator, so that the full amount of gas was delivered into the room. There were nine pipes altogether : five delivered into the room at different heights and four were inserted into the four burrows, and the mouths of the burrows where the pipes were inserted were choked up.

Three hundred and forty grammes of 98 per cent. potassium cyanide was decomposed. The resultant hydrocyanic acid gas calculated to be about 4·38 cubic feet at 26° Centigrade was delivered into the room of about 1,640 cubic feet capacity. The amount of potassium cyanide used would be equivalent to about $\frac{3}{4}$ oz. to 100 cubic feet air space. There was 35 minutes' exposure to the gas. By means of the observation rods the room was seen to be sufficiently free from the gas five minutes later. Forty minutes, therefore, were taken for the whole experiment. After the fumigation the fleas were examined at once and also three hours later to see whether they had revived.

Position.	Rats.			Fleas.		Remarks.
	Dead.	Sick.	Alive.	Dead.	Alive.	
On the floor . .	3	...	1	28 (all)	...	
4 feet from ground .	3	...	1	12 (all)	...	
6 do. .	2	...	...	...	...	
8 do. .	2	...	...	...	...	
12 do. .	3	...	...	10 (all)	...	
On the rafters . .	...	...	...	11 (all)	...	
Burrow A . .	1	...	...	15 (all)	...	For description of burrows, see page 12.
" C	1	...	...	11 (all)	..	
" D.—Obstruction in pipe found.	...	...	1	...	12 (all)	20 fleas were put in each of the four cages (2 of sand and 2 of bran). After fumigation, none were recovered by guinea-pigs, and therefore were presumably killed. For control, see Experiment III.
" B.—Observation burrow opened in midst of experiment.	...	1	...	10 (all)	...	

Experiment IX.

Into the same room of about 1,640 cubic feet capacity about 6·57 cubic feet of hydrocyanic acid gas were introduced, equivalent to about 1·2 ozs. potassium cyanide to 100 cubic feet air space. The exposure was for 40 minutes. Rats were let loose on the floor and put loose into the burrows to simulate natural conditions.

The gas was driven into the room by the fan. The disposition of pipes was similar to that in Experiment VIII.

Position.		Results.			Remarks.
		Dead.	Sick.	Alive.	
6 on the floor		3	1	2	For description of burrows, see page 12.
Burrow A, 3 put in	Blind burrows.	3	...	...	
Burrow B, 3 put in		3	...	...	
Burrow C, 4 put in		1	...	3 escaped.	
Burrow D, 3 put in		2	...	1 escaped.	

Experiment X.

The following experiments—X, XI, and XII—were made without the use of fan or tubes. The gas was produced in the room itself. First of all the sulphuric acid (commercially strong, specific gravity 1·83) was mixed with water (2 parts of sulphuric acid to 4 parts of water) generating heat. The mixture was made in a china vessel when small amounts were used and in a kerosine oil tin when large amounts were necessary. Then one part of potassium cyanide (100 per cent. Burgoyne Burbidges' Double Salt, for analysis see pages 2 and 3 of Report) was put in and the room at once quitted and the door shut.

In Experiment X a small, very air-tight godown was chosen, of about 346 cubic feet capacity.

One oz. potassium cyanide 2 ozs. sulphuric acid and 4 ozs. water were mixed. The exposure was for 40 minutes. The doors were then opened, but fumes of gas still were seen to be coming off.

The room was entered 15 minutes later. The fleas were examined at once and also two hours later.

Position.	Fleas.		Remarks.
	Dead.	Alive.	
15 fleas in a muslin bag 8 feet from the ground.	15	...	
6 fleas in a flannel bag on the floor.	6	...	
9 fleas in a cashmere bag . .	9	...	
10 fleas in a cotton bag enclosed in one rough blanket bag 5 feet from floor.	10	...	
7 fleas in a cotton bag enclosed in two blanket bags 5 feet from floor.	7	...	
11 fleas in a cotton bag enclosed in three blanket bags.	11	...	

Experiment X—*contd.*

A box was put into the room with fleas in bags in different positions.

POSITION.	Result.	REMARKS.
On the top of all was a bag *with* 8 fleas .	8 dead (all) . .	50 fleas were put in each of 4 cages, 2 with sand at foot and 2 with bran. After the fumigation was over flea counts were made on guinea-pigs three times at intervals of several hours and none were recovered. All, therefore, were presumably killed. For controls, see the end of Experiment III.
Then came a durree, trousers, and a coat in folds.		
Then came No. 2 bag with 10 fleas .	Immediately after the godown was opened all the fleas looked dead, but two hours later 4 were found dead and 6 alive.	
Then came a pair of trousers, a coat, and a durree.		
Then No. 3 bag with 7 fleas . . .	4 alive; 3 dead.	
Then came several layers of a chudder with No. 4 bag below it.	9 (all) living two hours after opening the godown.	
Then came a blanket in 8 layers with No. 5 bag below.	7 alive; 3 dead, two hours after opening the godown.	
Then several layers of a rug with No. 6 bag below.	5 dead; 4 alive, two hours after opening the godown.	

The following experiments—XI and XII—were made to determine whether the simple process above described would disinfect the large room of 1,640 cubic feet capacity described on pages 11 *et seq.*, containing burrows, so dispensing with the fan and complicated arrangements of generator and tubes. It will be seen that the burrows were not penetrated even with the 1 oz. of KCN to 100 cubic feet used in Experiment XII.

. Experiment XI.

Eight ozs. of potassium cyanide (Burgoyne Burbidges' Double salt 100 per cent.) 16 ozs. of sulphuric acid specific gravity 1·83 and 32 ozs. of water were mixed—a proportion of about $\frac{1}{2}$ oz. to 100 cubic feet.

The exposure was for 50 minutes. Fifteen minutes later the room was entered and was examined at once on opening the godown and also three hours later.

Position.	Rats.			Fleas.		Remarks.
	Dead.	Sick.	Alive.	Dead.	Alive.	
On the floor . .	2	1	1	20 (all) dead.	...	
4 feet from the floor .	...	...	2	8 dead	...	
5 do. .	5	...	...	30 dead	...	
6 do. .	1	...	...	...	...	
10 do. .	1	...	2	21 dead	5	
Rafters . . .	...	...	...	8 dead	6	
Burrow A } Blind burrows.	...	...	1	...	7	For description of burrows, see page 12.
" B } Blind burrows.	...	...	1	...	7	
" C } Two way burrows.	...	...	1	...	8	
" D } Two way burrows.	...	...	1	...	7	

Experiment XII.

Same room. 16½ ozs. of potassium cyanide (same salt as in Experiments X and XI), 32 ozs. of sulphuric acid of specific gravity 1·83 and 64 ozs. of water—about 1 oz. of KCN to 100 cubic feet of space. Exposure 50 minutes.

Position.	Rats.			Fleas.		Remarks.
	Dead.	Sick.	Alive.	Dead.	Alive.	
On the floor . .	1	2	1	21	...	
4 feet from floor . .	2	1	2	9	...	
6 do. . .	3	...	1	35	...	
10 do. . .	2	...	1	16	2*	* These appeared dead on opening the godown, but recovered 3 hours later.
Rafters . . .	...	...	...	2	9	
Ledge near open space between roof and smaller end wall.	...	...	...	7	2	
Burrow A Blind burrows.	...	...	1	...	6 (all)	For description of burrows, see page 12.
„ B	...	...	1	...	9 (all)	
„ C Two way burrows.	...	...	1	...	9 (all)	
„ D	..	...	1	...	8 (all)	

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BY

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